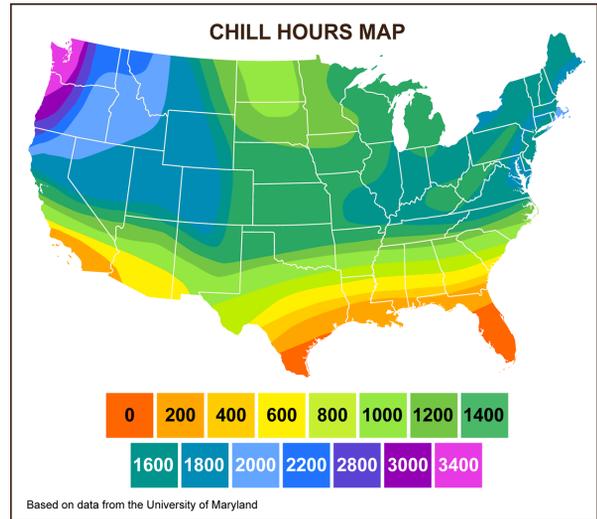


# Climate Change and WINTER CHILL

## What is Winter Chill?

During cool months of the year, many perennial crops lie dormant, resting up for spring when they will bloom and begin the reproductive development growth that gives us fruits, nuts, and grapes for wine. Perennials maintain a sort of internal ledger during winter dormancy, adding up the amount time they have been exposed to cool temperatures beginning in the fall. This internal accounting acts as a seasonal cue that governs the plant's phenology. Different crops and different crop varieties have evolved or been bred to require different amounts of accumulated winter chill, and this "chill requirement" is one agroclimatic metric important to the success of crop cultivation in any given location.



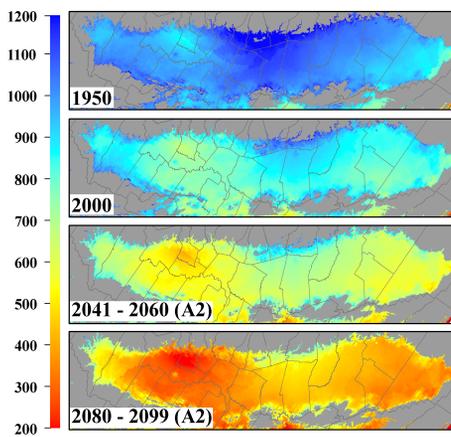
*Above: Average winter chill hours across the US*

## How is Winter Chill Accumulation Calculated?

### Four Models for Calculating Winter Chill

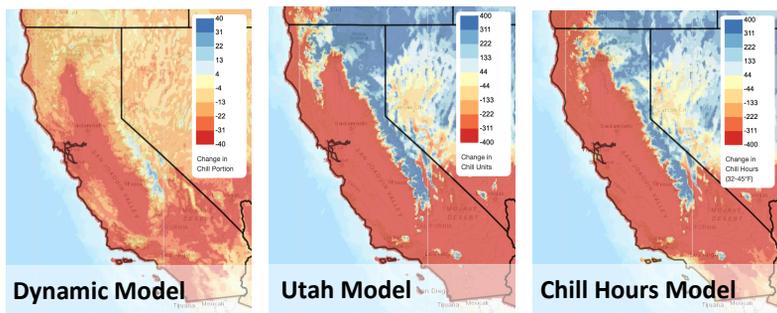
- Chill Hours Model (sum of hours below 45°F, earliest definition for chill accumulation)
- Modified Chill Hours Model (sum of hours 32-45°F, most commonly used model across US)
- Utah Chill Units Model (best for temperate areas with cold winters, warm temperatures can un-do chill accumulation)
- **Dynamic Chill Portions Model (best for California & temperate areas with mild winters, warm temperatures can un-do accumulation)**

## What Does Climate Change Mean for Winter Chill Accumulation?



As winters warm, California's perennial crops will be exposed to fewer hours of chilling temperatures. Research has shown that winter chill has seen a decline since the mid-20<sup>th</sup> century, and this trend is anticipated to continue with climate change. In fact, by the end of the 21<sup>st</sup> century, winter chill in the Central Valley may be less than 25% of what it is today. While low-chill crops may continue to thrive in this warmer winter environment, adaptation efforts may be necessary for California to continue cultivating high-chill crops like walnuts, pistachios, or cherries (Luedeling et al. 2009).

*Left: Winter chill declines in the Central Valley under climate change (Luedeling et al. 2009)*



Regardless of which winter chill model is used, climate change reduces winter chill accumulation over California's agricultural regions. In areas where winters are cold, the number of hours with temperatures 32-45°F may increase.

*Left: Maps from [ClimateToolbox.org](http://ClimateToolbox.org) showing change in chill under a high-emissions scenario.*

## Reduced chill accumulation means

- Irregular (delayed or extended) bloom
- Poor fruit or nut development
- Reduced yield and quality



*Delayed and uneven flowering due to a warm winter.  
Photo, UCCE Ventura*

## How Can Growers Adapt?

As growers replace their older crops with younger trees and vines, selecting cultivars with lower chill requirements provides a way to adapt to warming winters. For existing orchards or vineyards, kaolin clay masks may be applied to increase chill accumulation, and/or rest-breaking chemicals may be applied in years with low chill.

### Cultivar Selection

- Many crops have a range of chill requirements across multiple cultivars. UCANR provides Chill Portion requirements for more than 40 fruit & nut cultivars! (UCANR Fruit & Nut Research)
- Fruit breeding research is working to identify low-chill varieties.

### Clays and Rest-Breaking Chemicals

- Kaolin clay has been shown to increase chill accumulation by 5-7 portions during sunny, warm winters. (Doll 2015)
- Rest-breaking chemicals can be applied when 70% of the chill requirement has been met (UCANR Fruit & Nut Research)

## Where Can Growers Find More Information?

- For information on chill models, fruit and nut chill requirements, and a chill accumulation calculator for stations across the state, see UCANR's Fruit & Nut Research Weather Services site [http://fruitsandnuts.ucdavis.edu/Weather\\_Services/](http://fruitsandnuts.ucdavis.edu/Weather_Services/)
- For projections of future chill accumulation, see Climate Mapper on the Climate Toolbox website and select Agriculture as the 'Impact Area.' Projections from 3 chill models are shown. <https://climatetoolbox.org/tool/Climate-Mapper>
- For more farm or crop-specific information, growers can contact their local UC Cooperative Extension professionals <https://ucanr.edu/About/Locations/>

### References

1. Luedeling, E., Zhang, M., & Girvetz, E. H. (2009). Climatic changes lead to declining winter chill for fruit and nut trees in California during 1950–2099. *PLoS one*, 4(7).
2. Doll, D. (2015). Kaolin clay may be useful for increasing chill accumulation in pistachios. <http://thealmonddoctor.com/2015/10/26/kaolin-clay-may-be-useful-in-increasing-chill-accumulation-in-pistachios/>

**Visit the California Climate Hub online!**

<https://www.climatehubs.usda.gov/hubs/california>